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Volume 3
Development Program Plan

FINAL REPORT

CIT PHOTOHELIOGRAPH DEFINITION STUDY

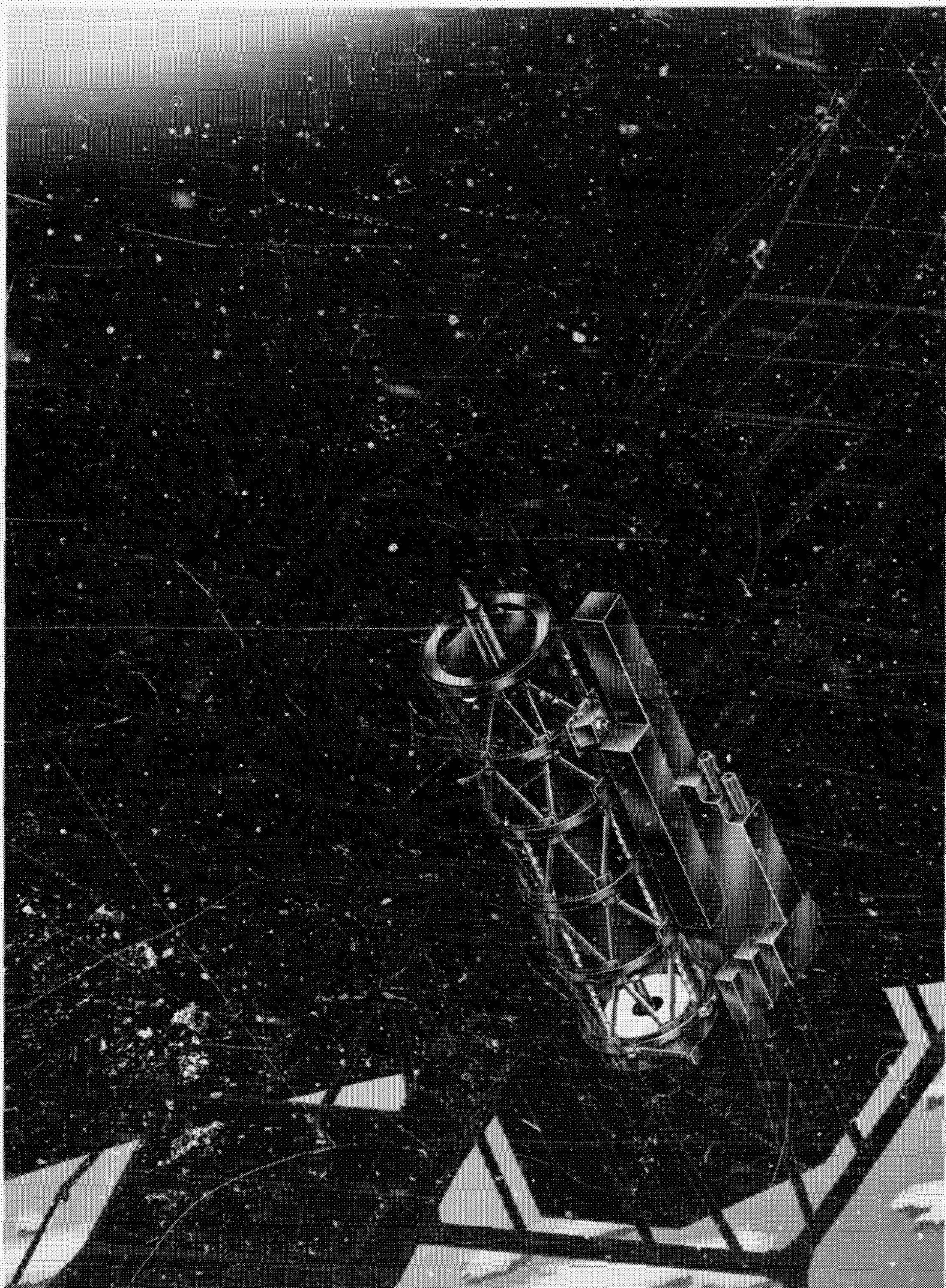
Prepared for
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Contract No. NAS8-30190

MSFC-DRL-212, item no. 3

APRIL 1971

BALL BROTHERS RESEARCH CORPORATION
SUBSIDIARY OF BALL CORPORATION
BOULDER, COLORADO



CIT PHOTOHELIOGRAPH

BALL BROTHERS RESEARCH CORPORATION

Volume 3
Development Program Plan

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FINAL REPORT

F71-02

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FOREWORD

The Photoheliograph Definition Study was performed for NASA/MSFC under Contract NAS8-30190. This four-volume Final Report is the product of this study. The study was performed under the technical direction of:

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ABSTRACT

This study has resulted in an improved design of a Photoheliograph compatible with an ATM class mission. Previous work was reviewed and critical problem areas were analyzed. The system requirements were configured into three modules: the telescope, instrumentation, and support modules. The telescope module performs the function of imaging a portion of the Sun for measurement by the complement of data cameras in the instrumentation module. The electrical and electronic management equipment is contained in the support module. The Photoheliograph is compatible with the ATM and also with other carriers of major scientific hardware. The Photoheliograph system can be developed using present technology and could be available for a 1976 mission.

The final report on the study is presented in four volumes:

- Volume I - Executive Summary
- Volume II - Detailed Technical Report
- Volume III - Development Program Plan
- Volume IV - Development Program Cost Estimates

CONTENTS

ILLUSTRATIONS

Section 1
INTRODUCTION

The space Photoheliograph has been the dream of solar astronomers since the dawn of the space age. From above the Earth's atmosphere the Sun's features can be observed in fine detail, limited only by characteristics of the telescope. Dr. H. Zirin, of California Institute of Technology, has for many years been spearheading the development of the space Photoheliograph. As the capability to orbit large payloads made a significantly large space Photoheliograph possible, Dr. Zirin's concepts evolved to the point that a feasibility study was required. This was performed by Dr. Zirin, his staff, and a task force at the Jet Propulsion Laboratory (JPL) in 1967. This study, although prematurely terminated in 1968 due to lack of funds, did indicate that a space Photoheliograph was feasible, and that the major technological problems could be engineered.

Development of the space Photoheliograph continued in 1969 with the fabrication of a 65-centimeter telescope based on the conclusions of the JPL study. This engineering model is being built by Ball Brothers Research Corporation for Dr. Zirin and will undergo tests and evaluation in the near future.

This Definition Study has resulted in further analysis of critical design areas and in an improved design concept for the Photoheliograph. The trade-off results and the design concept are presented in Volume II of this Final Report. Volume I is the Executive Summary of the study.

This volume of the Final Report for the Photoheliograph Definition Study contains the Development Program Plan covering Phase C

(Design) and Phase D (Development/Operations). This overall Program Pla⁻ contains the planning for the major activities during Phase C&D: engineering, manufacturing, and test, as well as support and management functions. In addition an analysis of the Phase C&D schedule is included, covering the feasibility of meeting the program milestones.

The supporting cost data for this Program Plan are contained in Volume IV.

Section 2
SUMMARY DISCUSSION

Development of the CIT Photoheliograph for a Skylab/ATM mission will require a comprehensive program of design and development operations. Such a program has been planned during this study to sufficient depth that its feasibility is well established. The overall plan is based on several major programmatical guidelines:

- Second quarter, 1976 launch
- Three complete systems - Design Verification Unit, Proto-Flight and Flight Unit
- Reliability goals for Category II - Mission success equipment
- Forty-five (45) month program duration.

The program activities divide into two major categories:

(1) Operations
- Engineering
- Fabrication
- End-Item Integration and Test

(2) Planning and Control
- Reliability and Quality Assurance
- Configuration Management
- Administration.

These activities and the three hardware systems have been combined into a project structure that is the basis for the program planning. This structure was built into a five-level Work Breakdown Structure (WBS) incorporating all major instrument assemblies conceived during the design phase of this study. From this WBS, the program activity plans were generated to define the detailed program milestones. These plans are described in Section

Using the WBS and program activity plans, logic diagrams were generated covering all work efforts required for the program. These logic diagrams were formulated into PERT networks and time estimates were made for each activity. Analysis of the logic paths was performed to determine the critical program paths. This analysis was iterated until the total program was well balanced in terms of manpower and resources utilization, as well as funding requirements.

By means of this detailed program planning, we have identified the "longest" work paths in the program. Analysis of these paths has shown that the design and fabrication effort can be accomplished within the 45-month program schedule. Therefore, since all other work effort has considerable contingency time, we conclude that the Development Program Plan is very feasible and should present no major schedule problems.

Section 3
PROGRAM REQUIREMENTS

3.1 PROGRAM PLAN

The overall Phase C&D Program Plan for the Photoheliograph is depicted in Fig. 3-1. The major activities (engineering, fabrication, test, and program management and controls) are divided into the system design effort, detail design, and the DVU, Proto-Flight and Flight Units to be produced. The relative schedule requirements and the major milestones for each of these activities are also shown in the figure.

Four basic project management steps have been employed in organizing the program plan for Phase C&D. These are:

- A work breakdown structure (WBS) for Phase C&D was developed.

- Work packages were developed. These work packages constitute the lowest level of the WBS, and are identifiable, measurable units of work required.

- The work logic networks were developed based on the integrated arrangement of all work packages contained in the WBS.

- The schedule was developed based on the integrated summary of the time required to accomplish each work package.

The work breakdown structure (WBS) for Phase C&D, Fig. 3-2, is primarily oriented to a hard[illegible]kdown, based upon the conceptual design of the Photo[illegible] developed under this study.

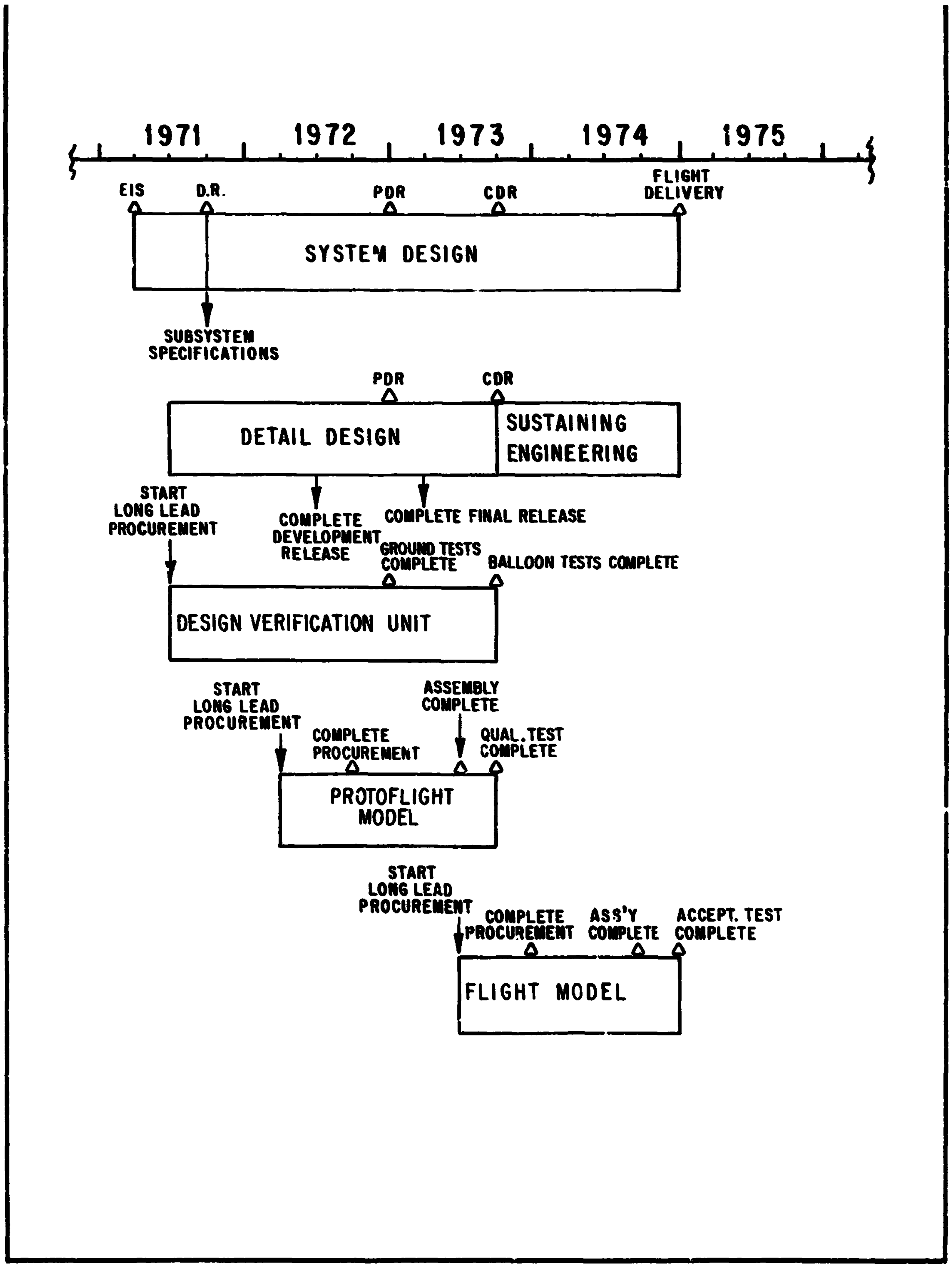

Fig. 3-1 Overall Photoheliograph Program Plan for Phase C&D

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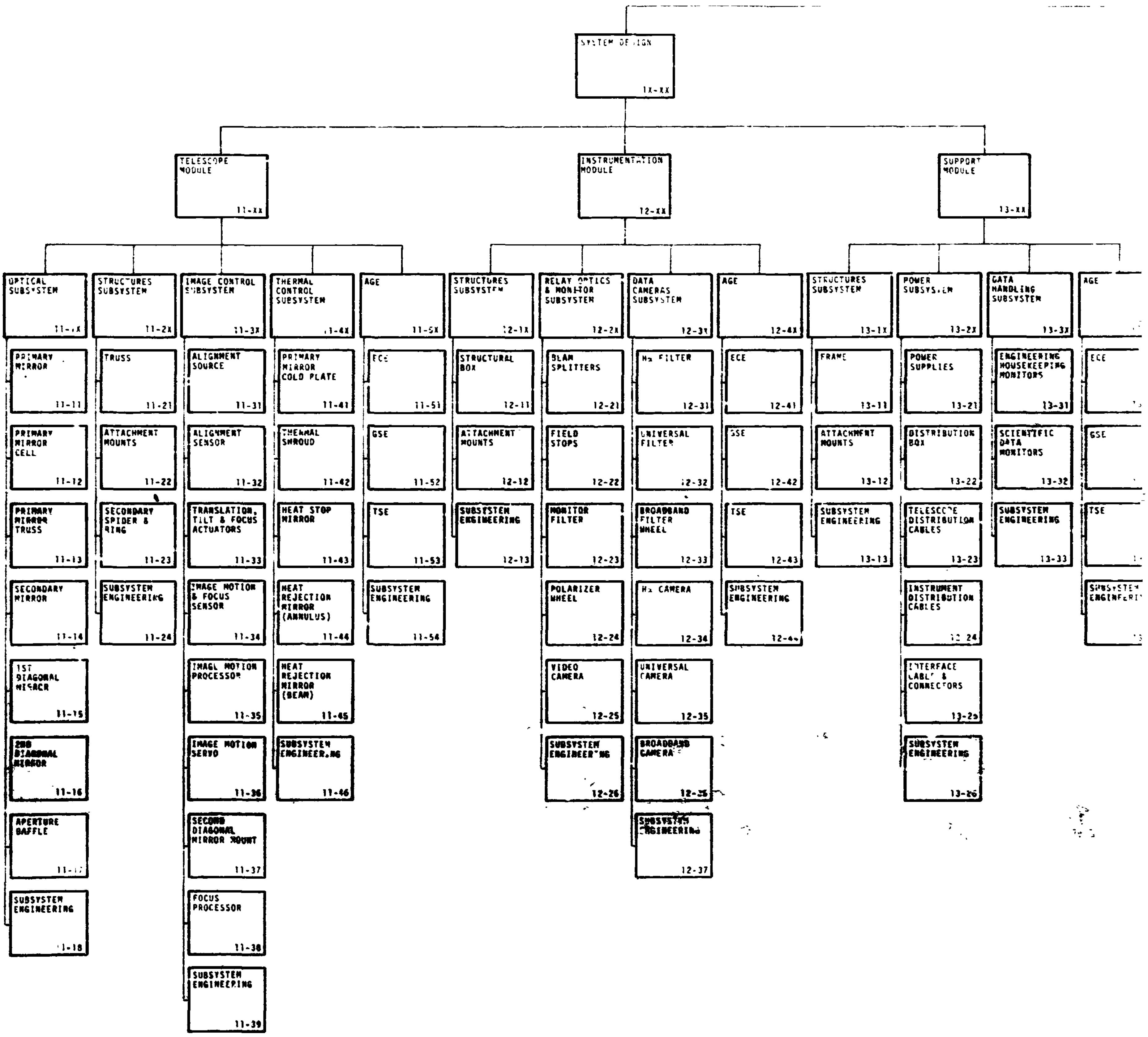

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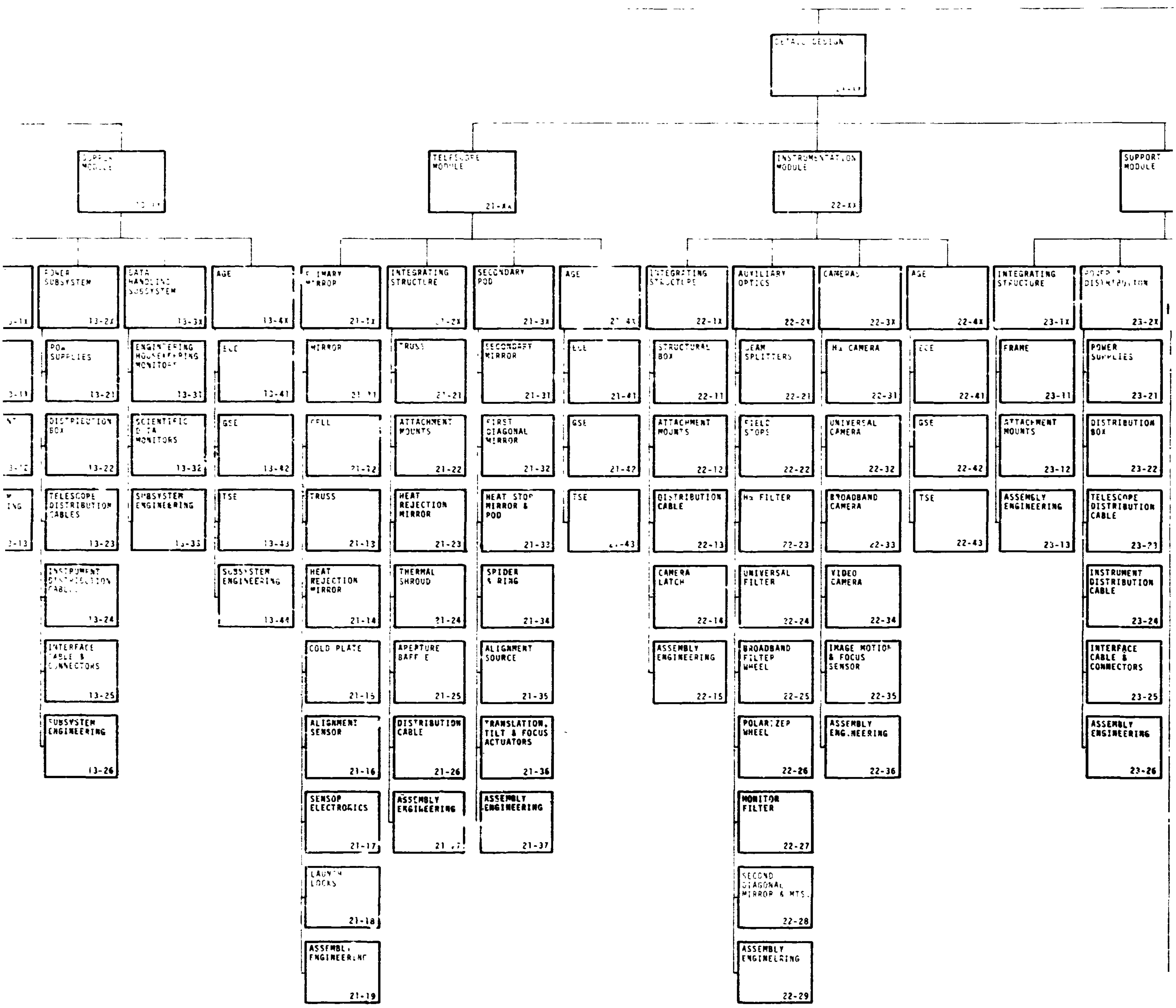

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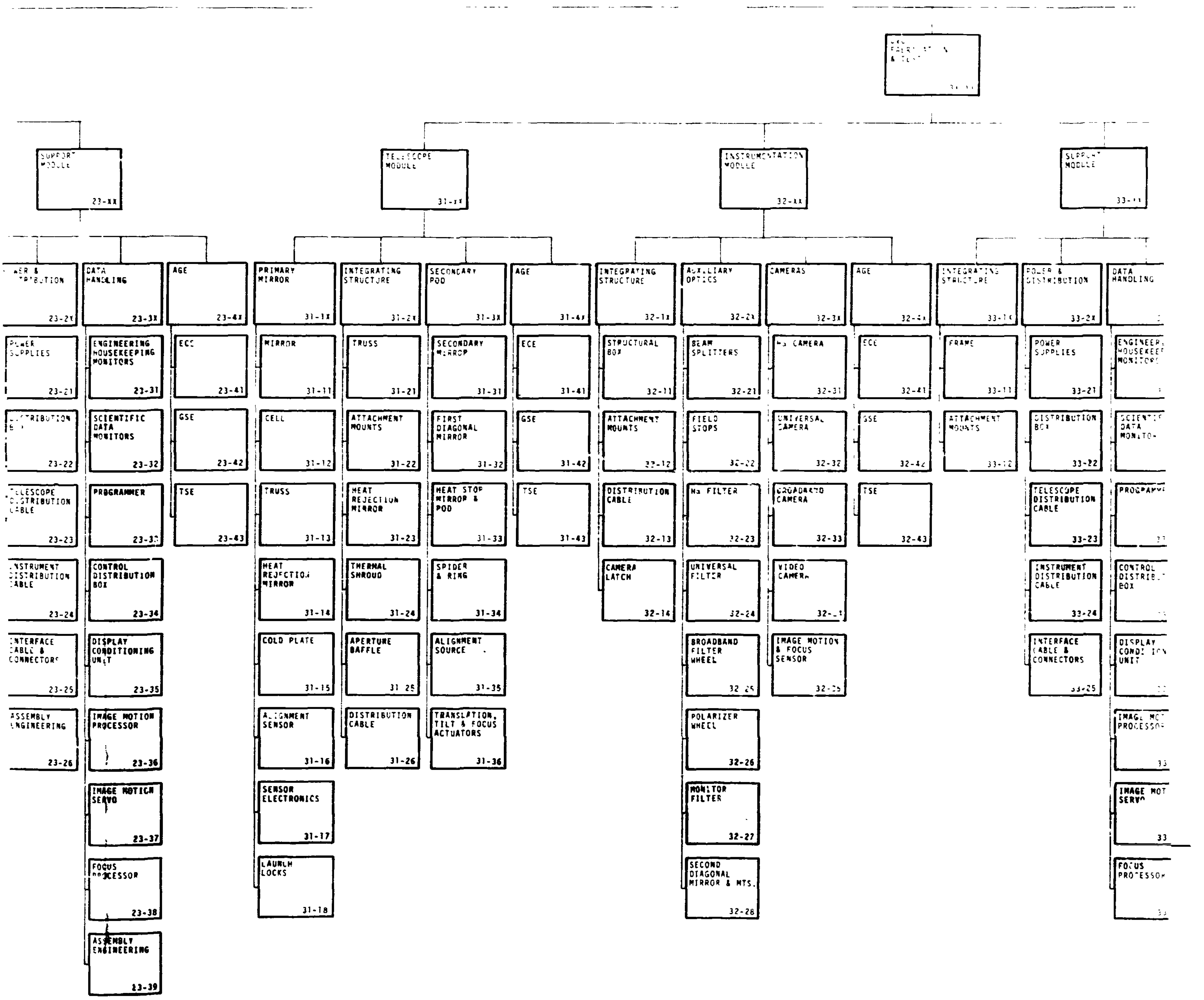

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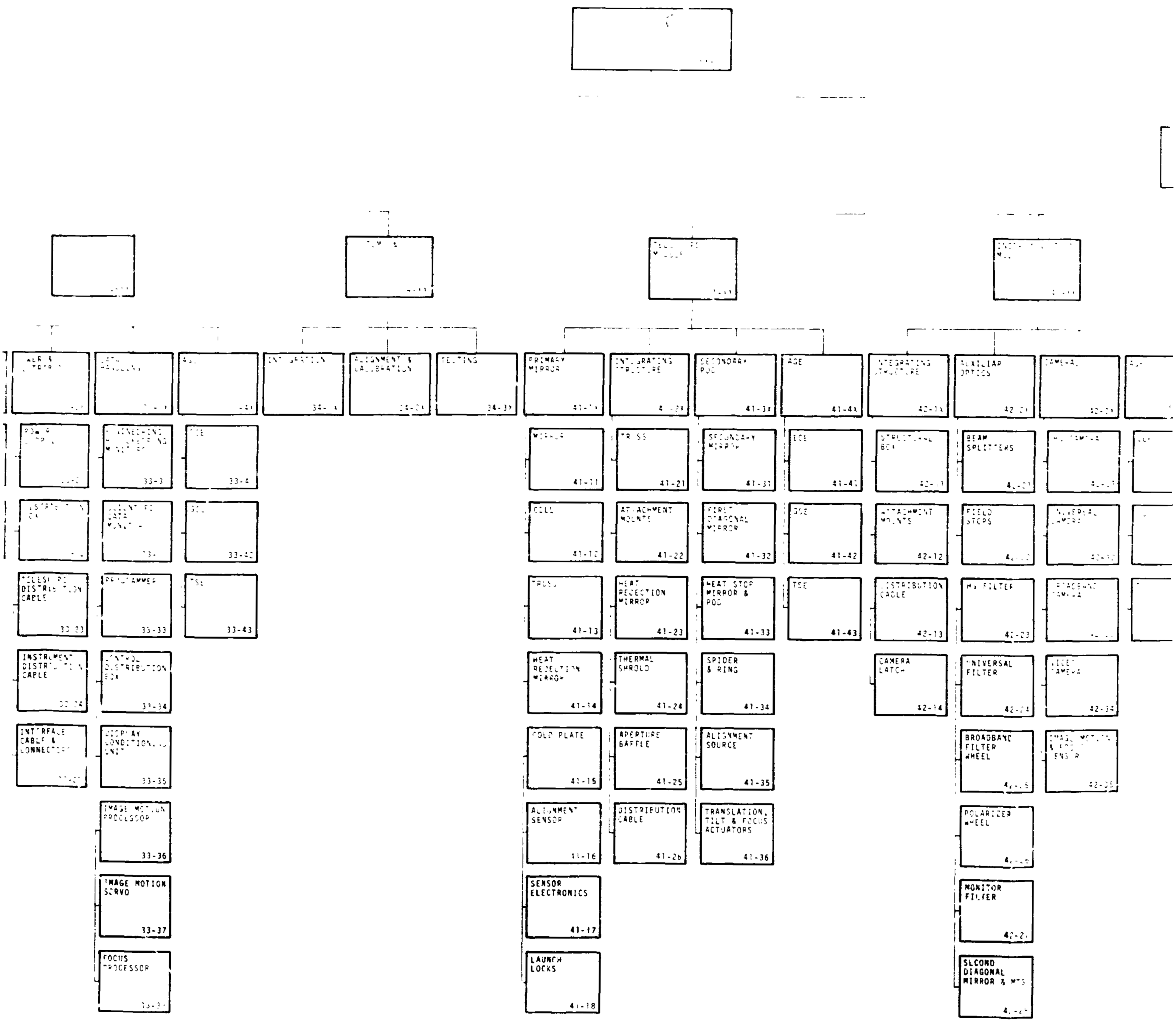

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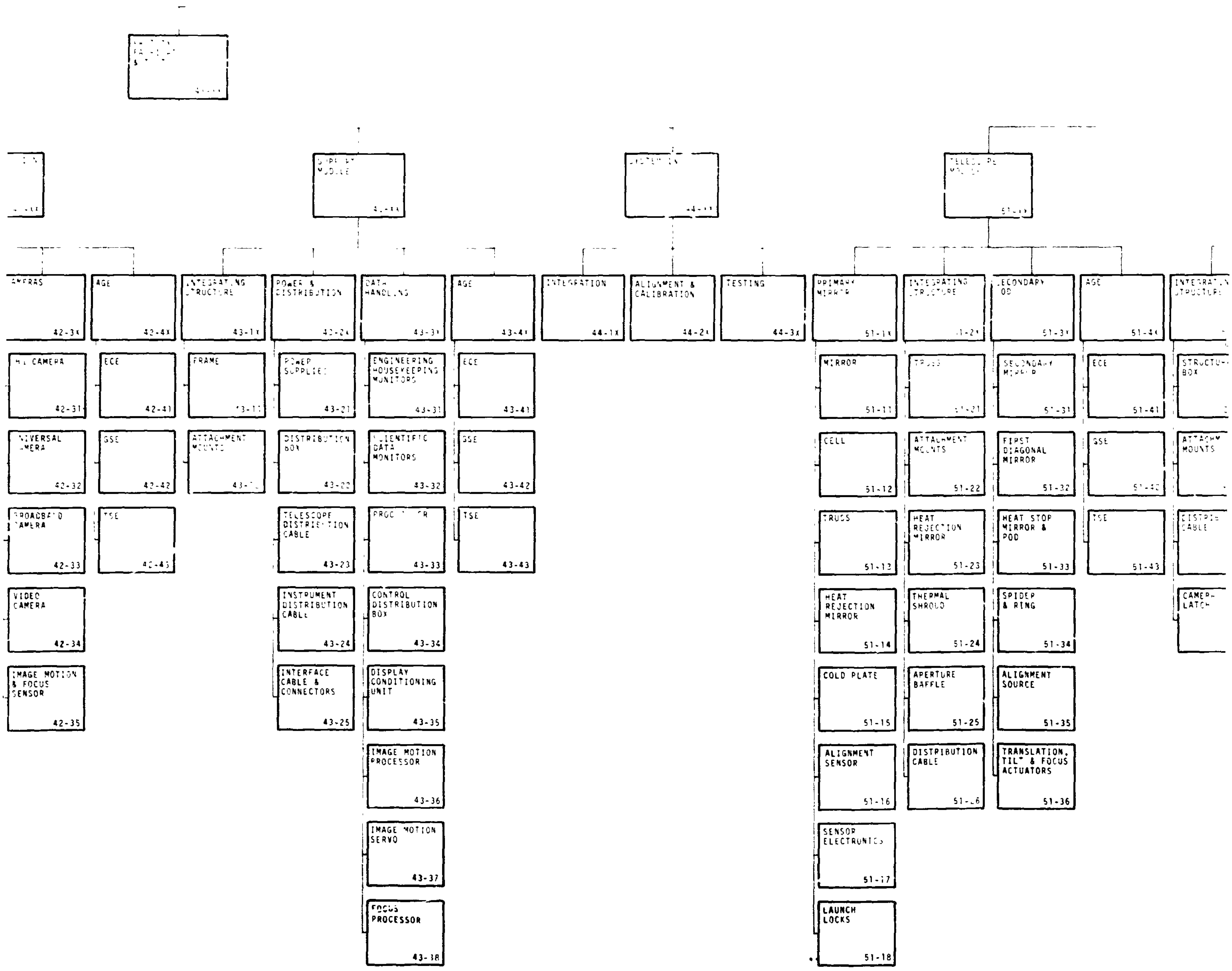

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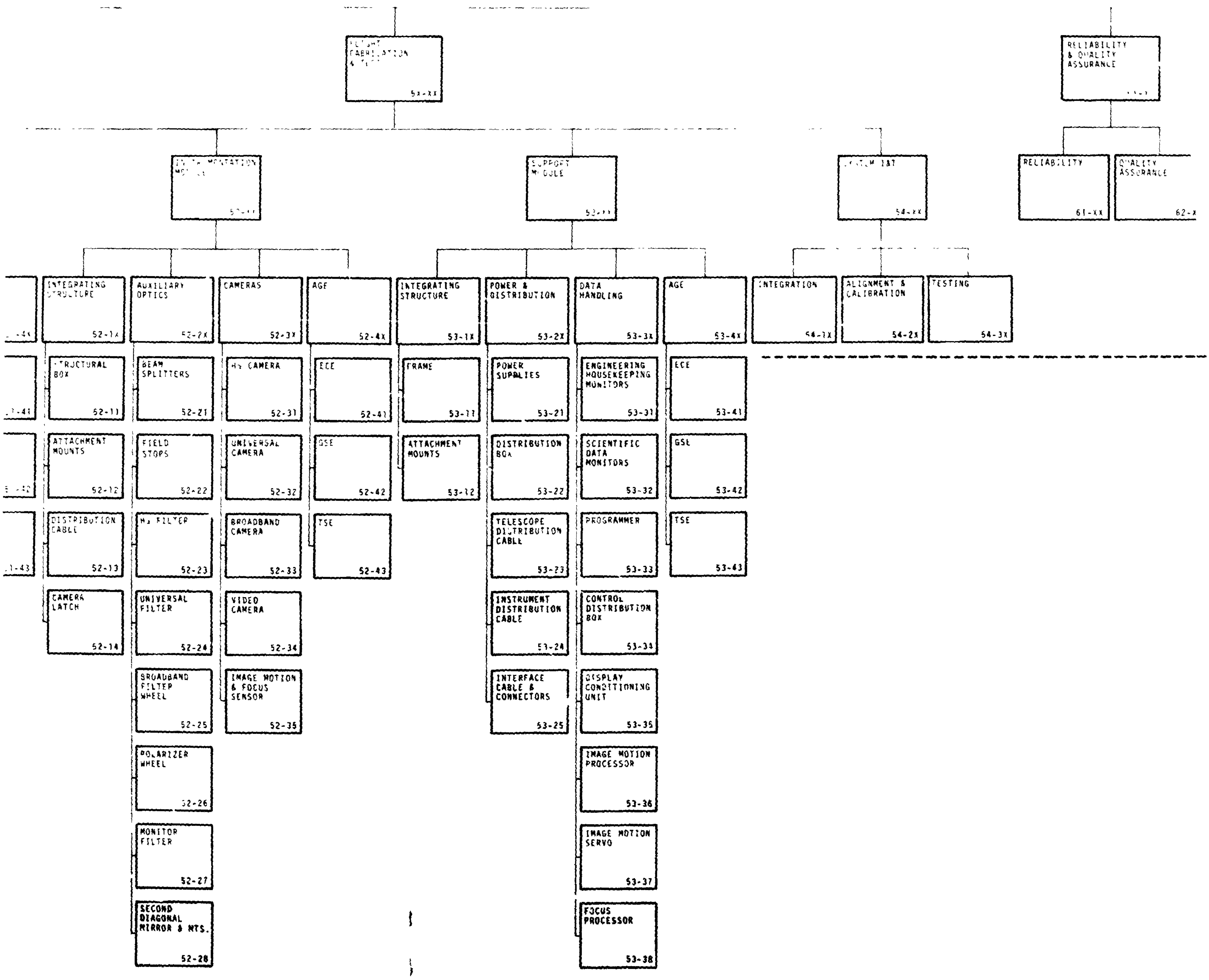

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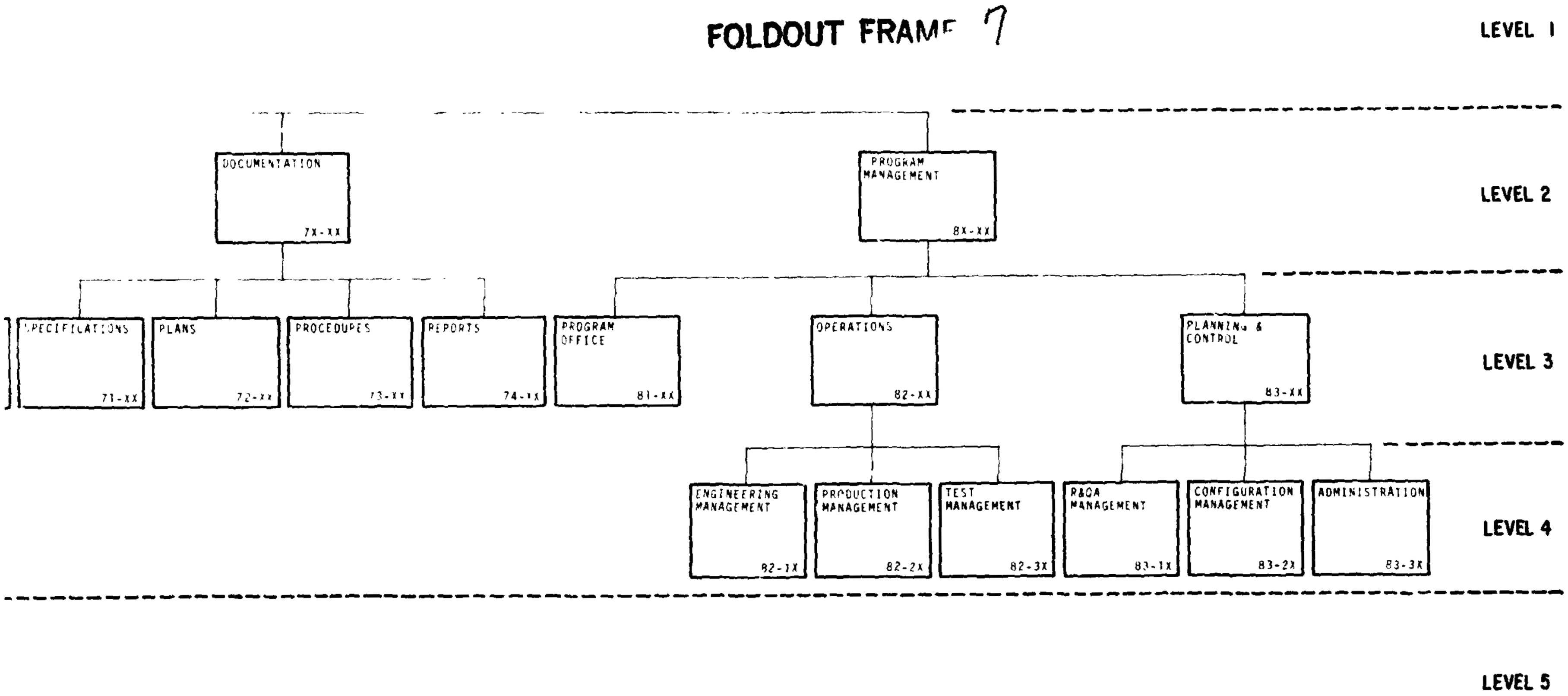

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Fig. 3-2 Photoheliograph Phase C and D Program Work Breakdown Structure

The objectives of the Phase C&D Program were the major consideration in evolving the WBS. Level 2 of the WBS identifies the major design objectives, end-items to be produced, and the management and control activities required. Each of the major objectives at Level 2 is broken down into its more detailed components, as appropriate. This approach to the WBS assures that the major objectives are fully supported by the lower level objectives. This further assures that the WBS is fully integrated and that each part of the project is consistent with and related to the project as a whole.

The four basic steps taken to organize the Phase C&D Program serve as the basis for total, integrated planning. The logic networks (PERT) have been structured to provide a correlation (including numerical coding) of the tasks in the WBS to the specific work activities. Figure 3-3 illustrates the correlation of the WBS tasks to the PERT activities. This uniform data base will make

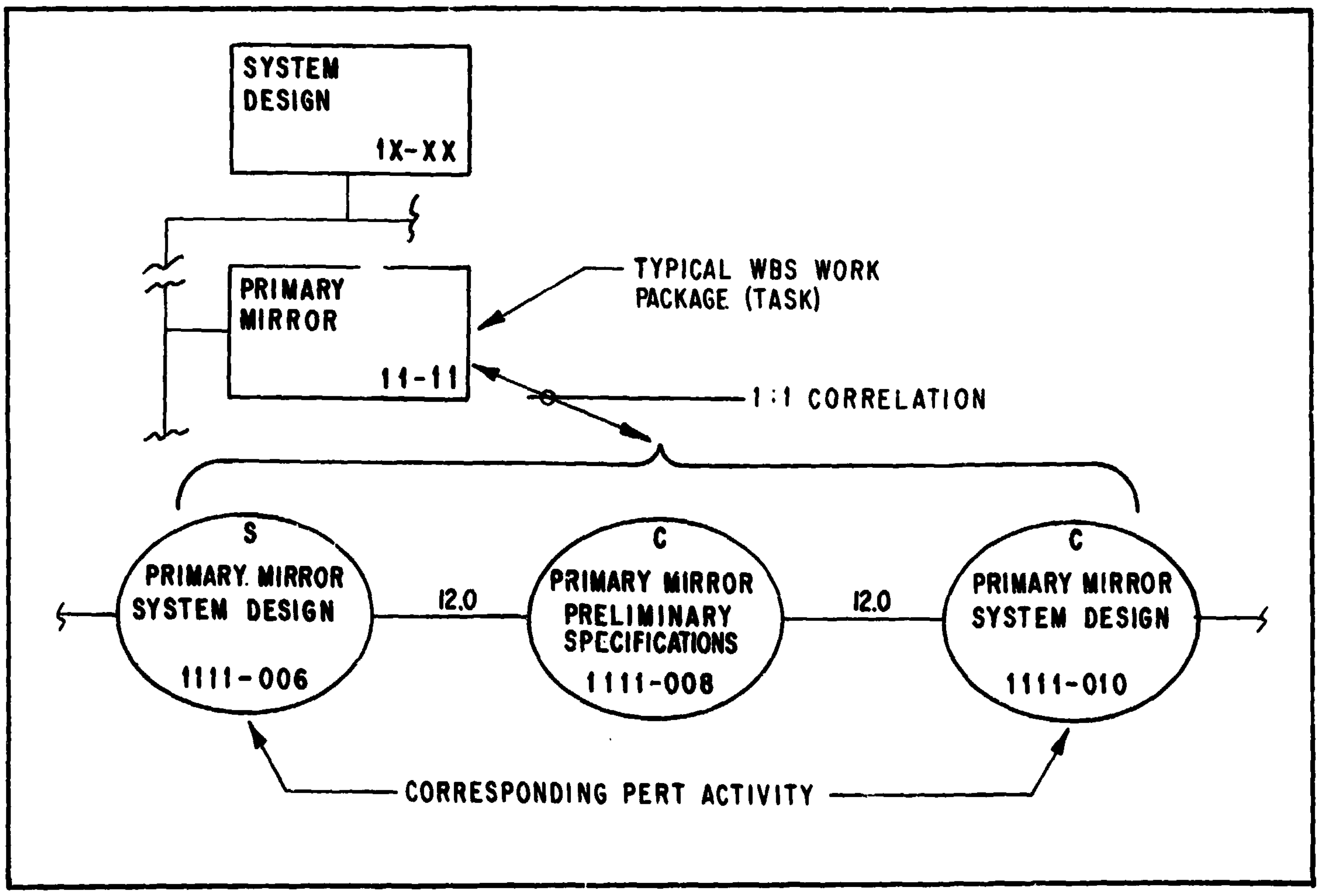

Fig. 3-3 Correlation of WBS Tasks to PERT

it possible to obtain consistent, timely and accurate program status throughout Phase C&D. Accomplishment of this integrated planning allowed the use of computer-based management techniques to determine the Phase C&D schedule and cost data.

Development of the specific plans for the major Phase C&D Program activities is based on the above planning. The plans for these major activities generally correlate to the major elements of work at Level 2 of the WBS and, therefore, serve essentially as major task descriptions. Plans are included for Engineering, Manufacturing, Test, Reliability & Quality Assurance, Configuration Management and Administration (Pars. 3.3 through 3.8, respectively, below). These plans depict the significant work elements of each of the major activities, as related to the overall schedule. A brief discussion of facilities requirements is included in Par. 3.9, and program management for Phase C&D is defined in Par. 3.10.

A discussion of possible Supporting Research and Technology (SRT) is contained in Par. 3.2. The areas discussed represent the more significant technological advancements involved in the Photoheliograph design, and are therefore identified as possible SRT items.

3.2 SUPPORTING RESEARCH AND TECHNOLOGY (SRT) AND DIFFICULT TECHNOLOGY

There are several difficult technology areas represented in the Photoheliograph. None of these is clearly beyond the state-of-the-art, but development problems could represent a risk both in schedule and cost. For an optimum approach in the planning of the Phase C&D Photoheliograph program, additional early development work should be performed in the following areas:

- The H-alpha filter and the universal filter have not yet been packaged for space flight. Since the H-alpha filter can be viewed as a simplified version of the universal filter, concentration should be on the universal filter. We recommend an early program to define proper approaches for packaging and control of flight-quality universal filters.

- The mirror coatings have not yet been used in an application such as that of the Photoheliograph, where a twelve-month lifetime, thermal cycling, and high ultraviolet reflectance will be required of the primary mirror. While we feel that adequate coatings can be made, solid knowledge of the optical and thermal performance of the primary mirror coating is mandatory, and testing under simulated orbital conditions will be lengthy. We advise an early effort to define the details of the coating and the process for its application, followed by testing it under simulated orbital conditions.

- Image motion control systems have been built which are similar to that advocated here, but none have required the precision which we need for this application. An early brass-board program for the image motion tracker would help uncover engineering difficulties which could delay a flight program.

- To a lesser extent, confidence in the focus detection system scheme would also benefit from an early brass-board model. The focus detection brass-board could share some key components with the image motion control brass-board.

- The use of television cameras for the Photoheliograph's prime data would eliminate the need for EVA's by the astronauts, permit the principal investigator to interact much more closely with the instrument, and better lend itself to remote operation of the entire instrument. The lack of a television camera having sufficiently high resolution is the major impediment to this approach. An early development program for such a camera would greatly increase the prospective versatility of the Photoheliograph, and the camera would undoubtedly be usable on other optical systems in space.

3.3 ENGINEERING PLAN

This plan defines the engineering effort shown in the program plan, Fig. 3-1. The engineering plan covers systems design, detail design, design verification, end-item qualification, reliability and sustaining engineering. These program elements are shown in Fig. 3-4.

3.3.1 Systems Design

The systems design effort starts with Phase C go-ahead and continues throughout the program until delivery of the Flight Unit. This includes the preparation and updating of system and subsystem specifications, surveillance of detail design, production processes and end-item test planning, approval of released drawings, participation in design reviews, end-item testing evaluation corrective actions by the Material Review Board (MRB) and other sustaining engineering activities. Systems design ensures that the scientific objectives are met by the instrument system and that the design will interface smoothly with the ATM.

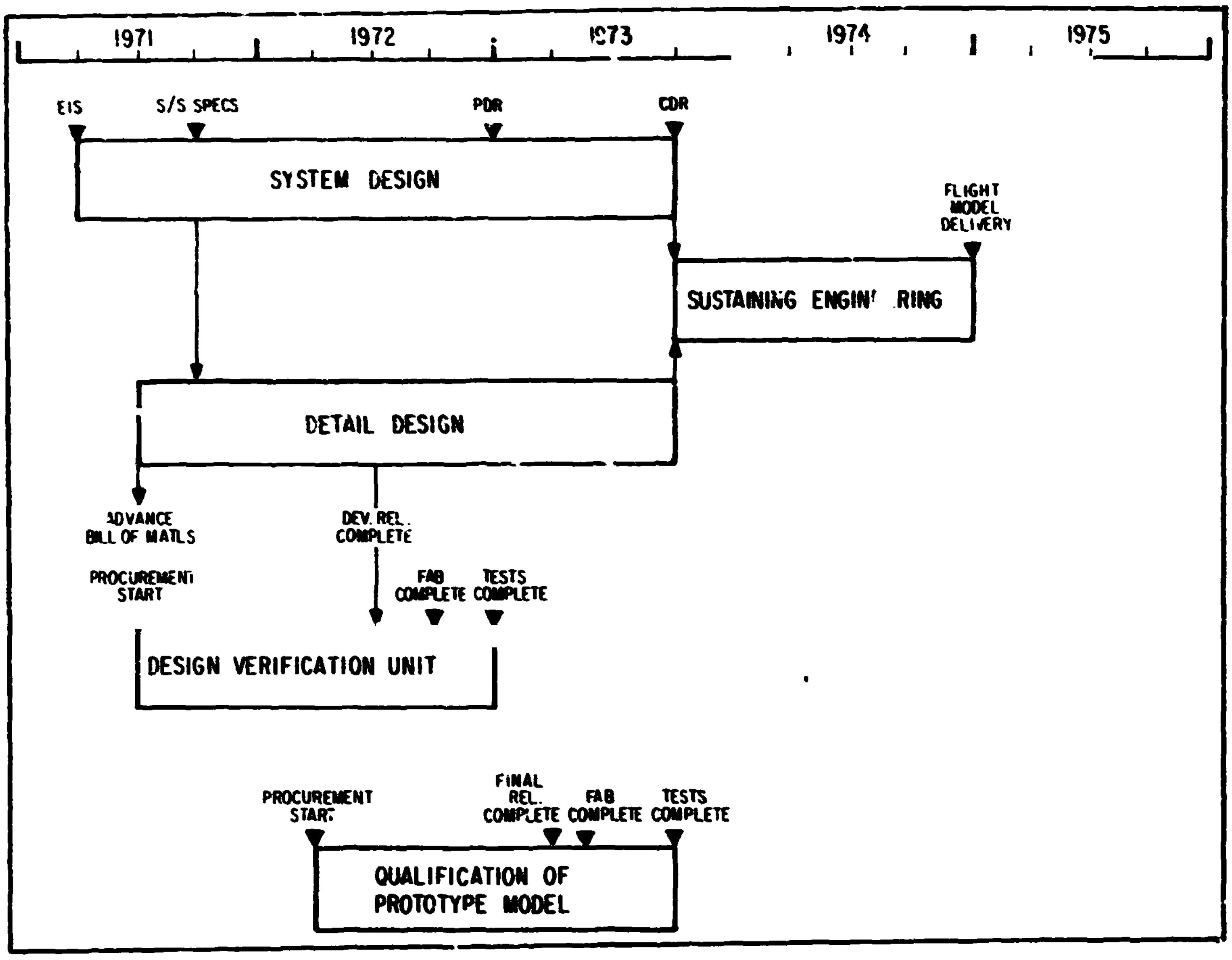

Fig. 3-4 Engineering Plan

The initial guideline for performing the system design effort is the End-Item Specification (EIS), which is the product of a complete Phase B preliminary design. From the EIS, the subsystem specifications are generated. Throughout the detail design effort, design reviews will maintain a system orientation to the effort. The major reviews are the preliminary design review (PDR) and the critical design review (CDR). The PDR is held about mid-way through the design phase, when the design verification work is completed. The CDR is held at the completion of the qualification efforts on the Proto-Flight Unit. System design efforts provide the structure throughout the program that ensures a balanced design and compliance with the scientific specifications.

3.3.2 Detail Design

The detail design effort starts with the release of subsystem specifications and continues throughout the program until delivery of the Flight Unit. This includes detailing of all parts and preparation of all drawings and procurement specifications, both for development items and flight-hardware releases. Included in this effort is the performance of breadboard and design verification tests. The major milestones shown in Fig. 3-4 are the control points for performing the detail design. These are: (1) development release; (2) PDR; (3) final release; and (4) CDR. The Design Verification Unit (DVU) is manufactured to the development release drawings, and the results of the DVU test program are the main input to the PDR. Similarly, the Proto-Flight Unit is manufactured to the final release drawings, and the results of the qualification test program are the main inputs to the CDR.

As the design evolution proceeds, the change control also changes from a general control at the development release milestone to a specific, tight control after the CDR milestone. In such a design evolution, the engineering changes will originate from the customer, the designer, or as a result of Material Review Board action correcting a discrepancy or a failure. Such engineering changes must be efficiently accomplished throughout the program, and the mechanisms for configuration management are discussed in that control plan, Par. 3.7.

3.3.3 Design Verification

One of the key steps towards achieving the high reliability required of the Flight Unit is to perform a series of design verification tests on engineering hardware early in the program.

This is a major engineering effort and is included in this plan in the form of the fabrication and test of a DVU, as shown in Fig. 3-4. The DVU will be fabricated to the development release drawings, which is the first step in verifying the design by proving that it can be fabricated.

A variety of in-process tests will be conducted on the DVU hardware at the assembly levels to investigate specific design questions. More extensive design feedback will come from the complete system tests, which will include environmental and functional checkout similar to that planned for end-item qualification. Two DVU balloon missions are planned as end-to-end verification that the design will yield the desired scientific data under orbital conditions. All changes resulting from the design verification activities will be used as inputs for upgrading the design before release of the final drawings.

3.3.4 End-Item Qualification

The final major engineering function performed on this program is the complete qualification of the end-item design. This qualification is performed on the Proto-Flight end-item. The Proto-Flight Unit is fabricated to the final release drawings; thus, the qualification is of the flight design. The qualification criteria are established in the End-Item Specification, and consist primarily of a series of environmental and functional system level tests. Since the Proto-Flight is a deliverable flight-quality end-item, these tests are controlled as required to maintain the reliability goals. The results of the qualification tests are the final major upgrading of the design and lead to the CDR.

3.3.5 Reliability Engineering

Reliability engineering is a major input to the design effort on this program. The selection of piece-parts that meet the high reliability standards is essential if the system's reliability goals are to be met. Reliability specialists provide a systems overview at all design reviews and by signature authority on final release drawings. A Failure Modes, Effects and Criticality Analysis, Part I, will be performed to ensure that the system reliability goal can be met with the released design. Reliability engineering is performed throughout the program duration, starting with the systems design and extending through end-item test surveillance, where failure analysis is performed and corrective action defined.

3.3.6 Sustaining Engineering

Following the CDR, a sustaining engineering effort is required to provide support for final alignment, calibration, and acceptance testing of the end-item. Any required design changes approved by the Change Control Board that arise after the CDR, must be incorporated in the design baseline. This activity also provides technical continuity into the field support phase, if required.

3.4 MANUFACTURING PLAN

This plan defines the manufacturing effort shown in the program plan, Fig. 3-1. The manufacturing plan covers the procurement for the fabrication of the DVU, Proto-Flight and Flight Unit end-items. Assembly and in-process testing are included up to the black-box level. System and/or end-item assembly and tests are included in the Test Plan, Par. 3.5. The major manufacturing efforts are shown in Fig. 3-5.

3.4.1 Production Engineering

The production engineering effort is required to ensure producible designs and to provide the production supervision throughout the fabrication phase. This effort starts during the system design effort

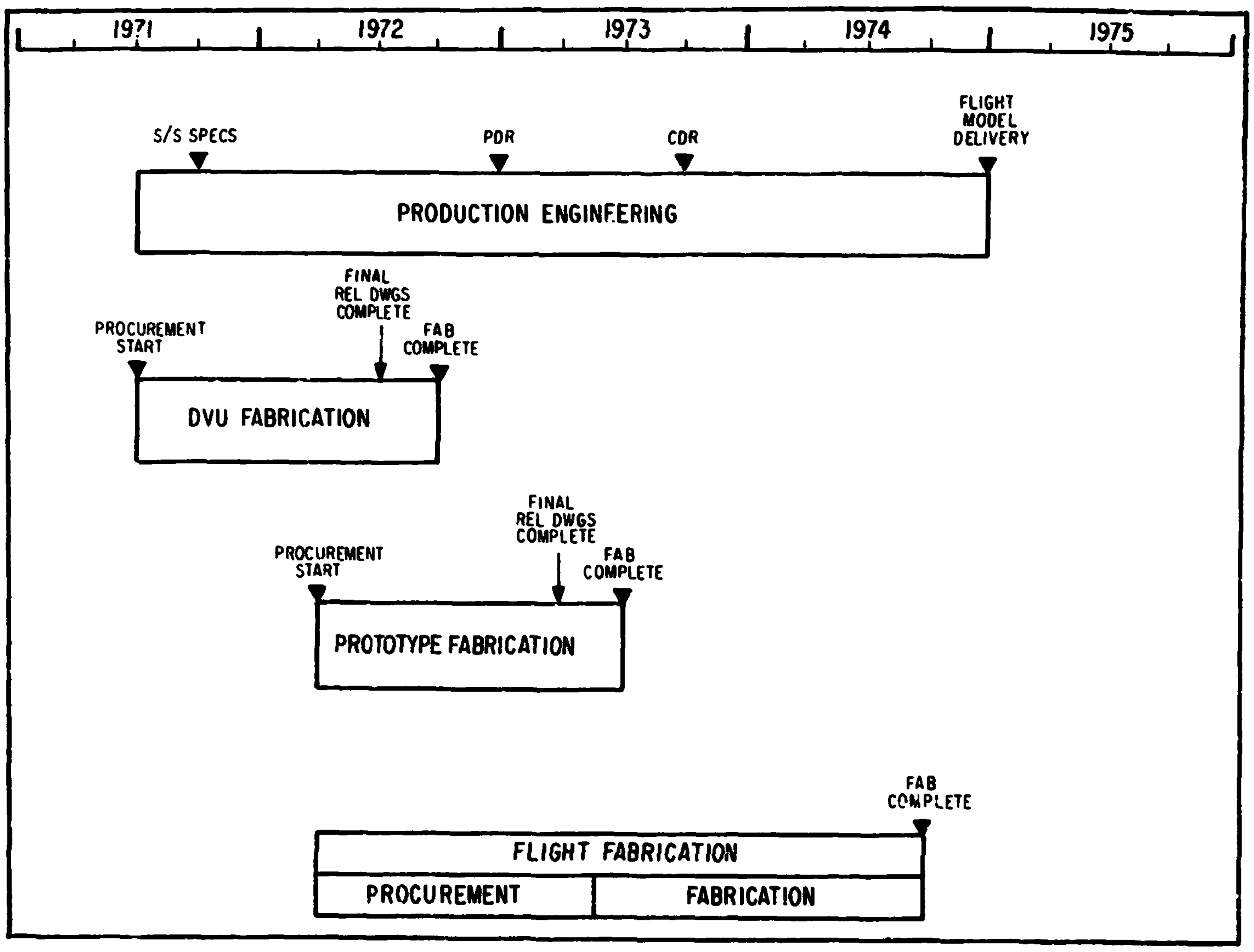

Fig. 3-5 Manufacturing Plan

described in Par. 3.3, and will continue until the Flight Unit end-item is delivered. Production engineering personnel participate in the system design evolution, as well as in the detail design efforts, to advise the designers as to feasible production techniques. Upon receiving released drawings, the fabrication effort for each end-item is planned in detail. The flow of the procurement, fabrication and assembly work is managed by production engineering personnel, to ensure that the assemblies that make up the system are manufactured to the design drawings and meet required quality standards.

3.4.2 Procurement

The procurement activities on this program require extensive surveillance to ensure that the hardware used in the end-item buildup is that called out in the design and by the quality standards. The procurements will vary from standard piece-parts to highly sophisticated subcontract items such as the primary mirror and spectral filters. The make-or-buy plan that is effective on this program will be used as an early guideline for procurement planning, and feedback from vendors will be required before the designs can be completed. The major subcontracts required for the program will be negotiated and controlled in accordance with standard aerospace practices. Vendor surveillance and receiving inspection of procured parts will be performed in accordance with the quality assurance plan in Par. 3-6. Similarly, the traceability of all parts will be maintained by storage in a bonded area until used in an assembly, in accordance with the quality assurance plan.

In most cases, procurement for the DVU will precede that for the Proto-Flight and Flight Units. Since the DVU hardware does not require end-item reliability, some compromises may be possible in the procured parts. However, in order to achieve the maximum feedback for design verification, every attempt must be made to obtain and use the designated high-reliability parts. Procurement for the Proto-Flight and Flight Units must adhere to the design requirements, and will include sufficient production spares to ensure completion of the end-items.

3.4.3 Fabrication and Assembly

Fabrication and assembly of the parts and assemblies of each end-item is the major function covered by the manufacturing plan. It starts with receipt of the piece-parts of materials and extends through the successful completion of each assembly or subsystem. These activities involve specialized fabrication processes associated with mechanical, electrical and optical shops. In addition, specialized facilities are required to support these activities.

The mechanical fabrication processes and facilities requirements are:

- Turning lathes
- Milling machines
- Rotary tables
- Boring mills
- Electron beam welding
- Riveting
- Grinding
- Precision boring
- Metal finishing
- Lubrication
- Welding
- Cleaning

The electrical fabrication processes and facilities requirements are:

- Soldering
- Welding
- Solid-state
- Video
- Potting
- Transformer winding
- Wiring
- Printed wiring boards
- Motors

The optical fabrication processes and facilities requirements are:

- Cer-Vit figuring (26-inch parabola)
- Silver mirror coating
- Diffraction-limit measurement
- Filters

All assembly work will be performed in controlled-access clean rooms, varying from good housekeeping for mechanical parts to Class 10,000 for electronic and optical parts.

Material traceability and operation certifications are not required on the DVU build, but are required on the Proto-Flight and Flight Units to meet the program quality standards. Similarly, in-process inspection is planned to ensure high-reliability parts and compliance with the design, and the quality plan provisions.

All functional parts will be tested before installation in the full system, to eliminate infant mortality or workmanship problems. The test data from these tests will serve as design feedback and become part of the overall system history.

3.5 TEST PLAN

This plan defines the test effort shown in the program plan, Fig. 3-1, or as part of the engineering or fabrication plans. The major emphasis of this plan is on the end-item integration and testing, but all program testing is mentioned to maintain a consistent approach to testing and to ensure a complete hardware history of the program and its end-items. The major testing efforts defined in the program are:

- Breadboard/brassboard design tests
- Materials and processes design tests
- Reliability parts evaluation tests
- Reliability failure analysis tests
- Manufacturing in-process tests
- Optical component acceptance tests
- DVU system functional/environmental tests
- DVU system balloon flight tests
- Qualification tests

- End-item functional tests
- End-item alignment/calibration tests
- End-item acceptance tests

This definition covers only the system integration and testing on the DVU, Proto-Flight and Flight Unit end-items. These activities are shown in Fig. 3-6.

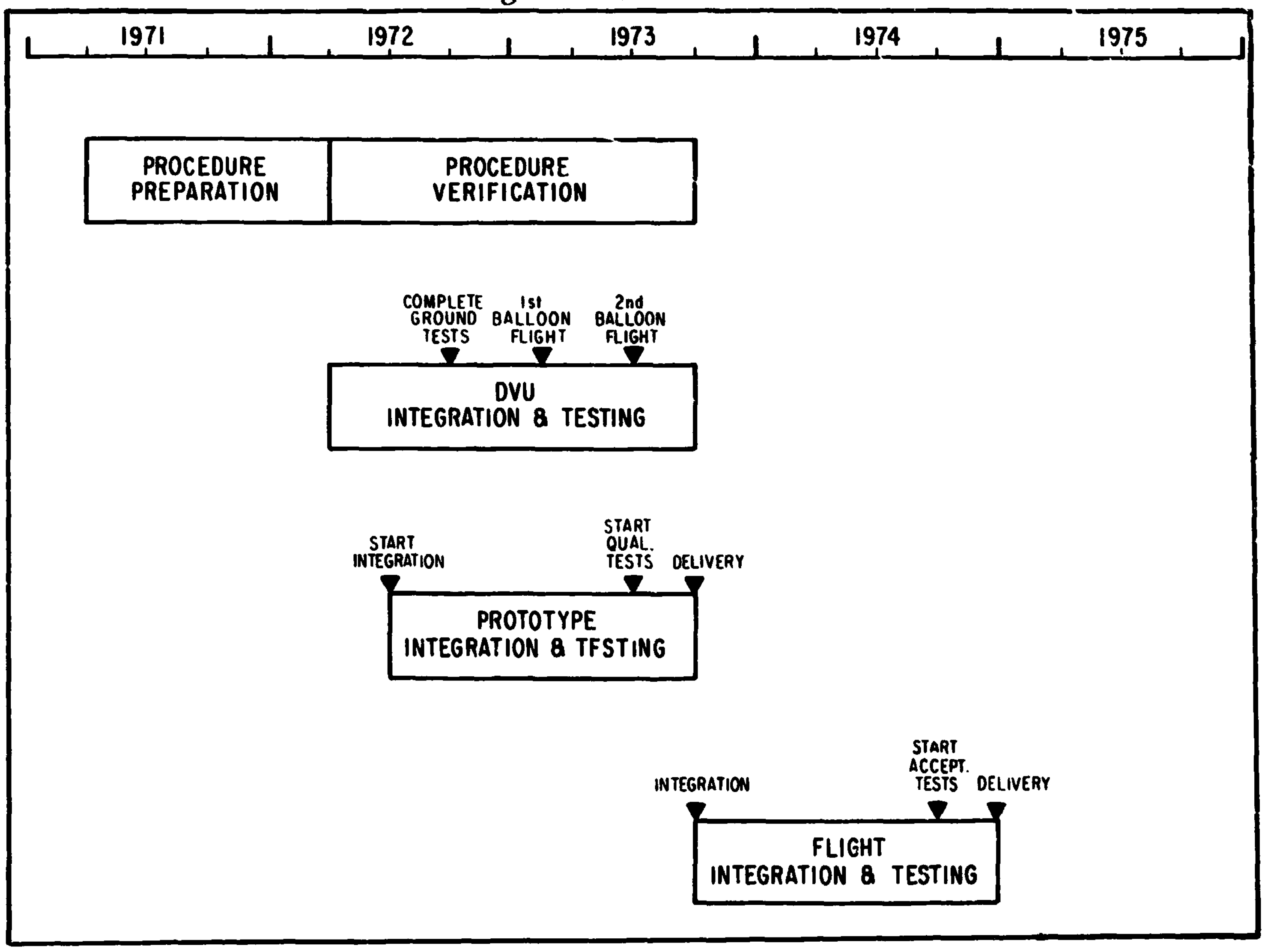

Fig. 3-6 Test Plan

3.5.1 System Integration

The black-boxes and assemblies completed during the fabrication phase of the program are integrated in this phase to complete the total Photoheliograph system. This process must be carefully planned and executed in the correct sequence. Some in-process tests or measurements must be included in the integration efforts.

Checkout of all functional subsystems must be carefully controlled by established procedures to ensure proper handling before power is applied and during powered operation. The in-process inspection criteria established during the fabrication phase are carried over and applied during system integration.

3.5.2 Calibration and Alignment

Some of the Photoheliograph system's final checkout will include calibration and alignment of optical elements, filters and data cameras. Both individual element calibrations and complete system end-to-end alignments will be required. The facilities required for these operations will range from labcratory calibration facilities, to existing ground-based solar observatories or large thermal vacuum facilities with a coelostat to bring the Sun's beam into the chamber or with artificial suns. As with the integration effort, these tasks on the Proto-Flight and Flight Units will be performed according to approved procedures and under quality surveillance.

3.5.3 System Functional Tests

System functional tests will be performed on all units: to provide performance data for design feedback, in the case of the DVU; in the case of the Proto-Flight Unit, for qualification; and in the case of the Flight Unit, for acceptance by the customer. These functional tests are repeated many times during the course of the final checkout, and the results form a baseline for later performance comparisons. The tests are controlled by established procedures and additionally, by quality surveillance on the Proto-Flight and Flight Units. The functional tests will exercise all Photoheliograph subsystems that can be operated in ground laboratories.

3.5.4 Design Verification Unit

Verification of the Photoheliograph design will be performed using the DVU fabricated to the development release drawings. It consists of a series of functional and environmental tests similar to those specified in the EIS for qualification. In addition, it will include two balloon flight missions for complete engineering evaluation.

The functional tests to be performed are those defined by the procedures generated for the end-item and system tests and, in execution, accomplish the additional task of verifying the test procedures. The environmental tests will be performed to the qualification levels defined in the EIS, which are based on the ATM specifications, and according to the preliminary procedures.

The two balloon missions will be conducted according to an approved flight plan. This test plan does not include in its scope provision of the balloon, gondola or launch facility.

The first balloon mission will follow the completion of all laboratory functional and environmental tests. As with the ground-based DVU tests, the test results and data will be analyzed as feedback to the design. A second balloon mission is planned to verify design improvements that result from both normal design changes and from data obtained in the first balloon flight.

3.5.5 Qualification

Qualification of the Photoheliograph design will be performed using the Proto-Flight end-item. It consists of a series of functional and environmental tests, as specified in the EIS, and as defined in the approved test procedures. The functional tests are as described in Par. 3.5.~; the environmental tests include:

- Sinusoidal vibration
- Random vibration
- Electromagnetic susceptibility
- Electromagnetic interference
- Thermal
- Thermal vacuum

Specialized acoustics testing may be required on some components, but is not planned on the complete system. All test operations will be performed using approved procedures with quality surveillance. The test results become the major inputs to the critical design review.

3.5.6 Acceptance

Each of the deliverable end-items, the Proto-Flight and Flight Units, must pass a series of acceptance tests as the final steps in the test program. These tests are specified in the EIS, and consist of both functional and environmental tests. The functional tests, as described in Par. 3.5.3, are intended to demonstrate complete system performance. The environmental tests are similar to those conducted during qualification, but at reduced limits; therefore, the Proto-Flight Unit will not require a second, separate series of acceptance tests. All acceptance tests are conducted according to the approved procedures and under quality surveillance. The test results are used as verification that the end-items are complete and ready for shipment.

3.6 RELIABILITY AND QUALITY ASSURANCE PLAN

This plan defines the efforts necessary to produce the required high-reliability end-items. It covers the control features of the program that are adopted from NASA Specification NHB 5300. Rather than citing every control feature in this specification, this plan will summarize those that are required to meet the reliability goals and quality standards. Figure 3-7 shows the program Reliability and Quality Assurance elements and their use as control factors over the underlying program effort.

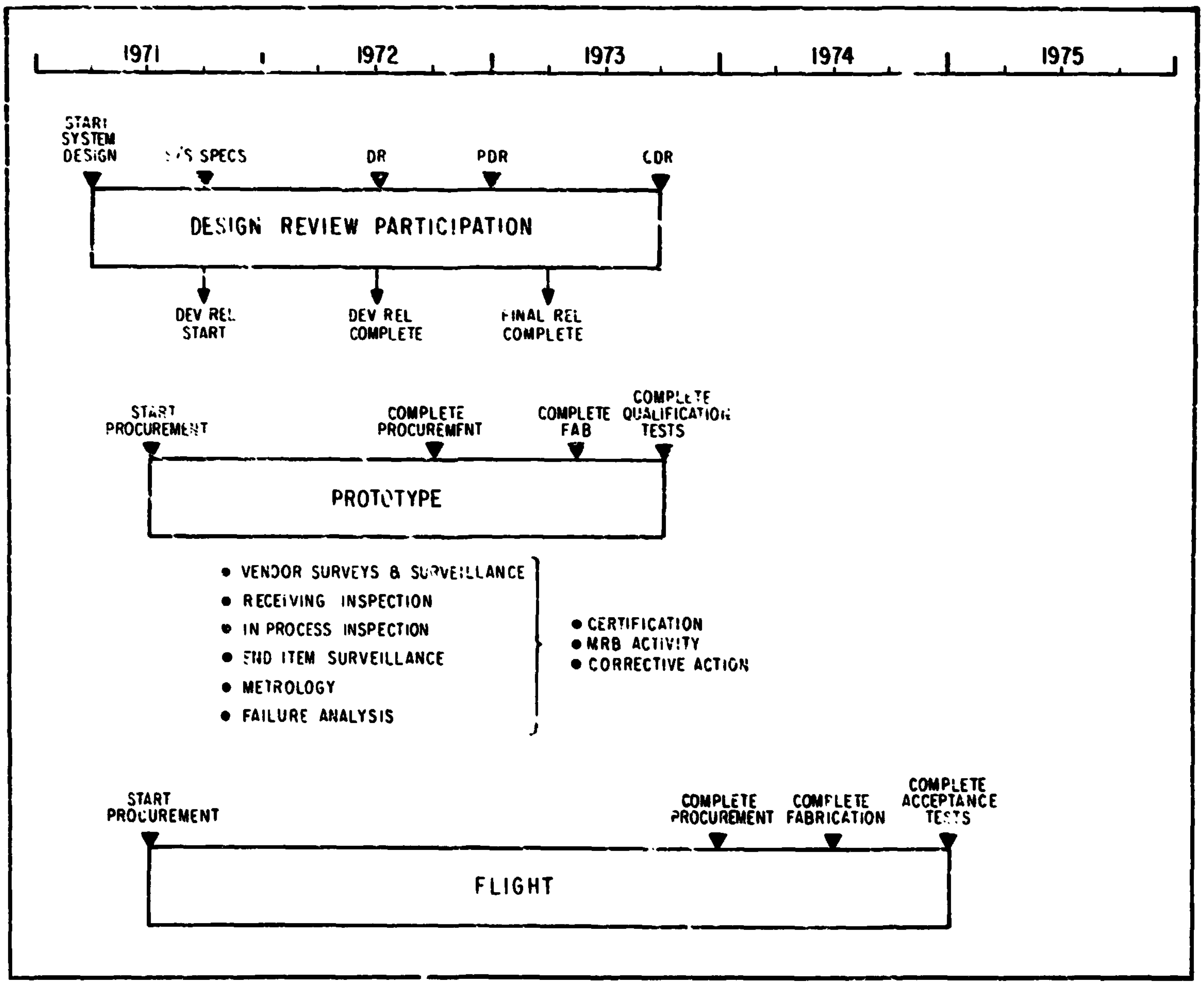

Fig. 3-7 Reliability and Quality Assurance Plan

3.6.1 Reliability Control

Reliability control is defined as that activity which provides the program with a check and balance aimed exclusively at achieving the maximum system reliability. This is differentiated from the reliability engineering described in Par. 3.3.5, which is one of the design disciplines. The major influence reliability control exerts over the program is the presence of such personnel at all design reviews and change board reviews. The specific role that contributes directly toward system reliability is that of failure analysis and suggestions for corrective action. As the major watch-dog over failures, reliability control exercises a significant role in maintaining system reliability in pursuing corrective actions. They emphasize improvement of reliability on the next end-item.

3.6.2 Quality Control

Quality control is defined as that activity which provides the program a check and balance over hardware activities. The Photoheliograph is defined as Category II equipment and, accordingly, the quality control plan for this program is adopted from NASA Specification NHB 5300. The major elements of quality control for this program include:

- Design review participation - insures the inspectability of the parts.
- Vendor surveys - qualifies prospective vendors for high-reliability work.
- Vendor surveillance - monitors vendor efforts and reports significant deviations.

- Receiving inspection - performs incoming inspection on all purchased parts to verify compliance with purchase specifications.

- In-process inspection - performs in-process inspections of all fabrication steps to verify compliance with design drawings.

- Certification - witnesses authentication of parts traceability and maintains certification records.

- End-Item surveillance - monitors all end-item activities to verify compliance with integration and test procedures.

- Non-conforming Material Report - Initiates MRR activity upon witnessing an out-of-specification condition.

- Metrology - maintains all measurement equipment used on the program in a current, calibrated condition.

3.7 CONFIGURATION MANAGEMENT PLAN

The magnitude of the Photoheliograph program requires that its configuration be controlled throughout the various efforts. The configuration management plan defines the major elements of this control function as they apply to the program. The two major activities are: (1) configuration control, and (2) configuration identification. The framework of the configuration management plan is shown in Fig. 3-8, and the major efforts are described below.

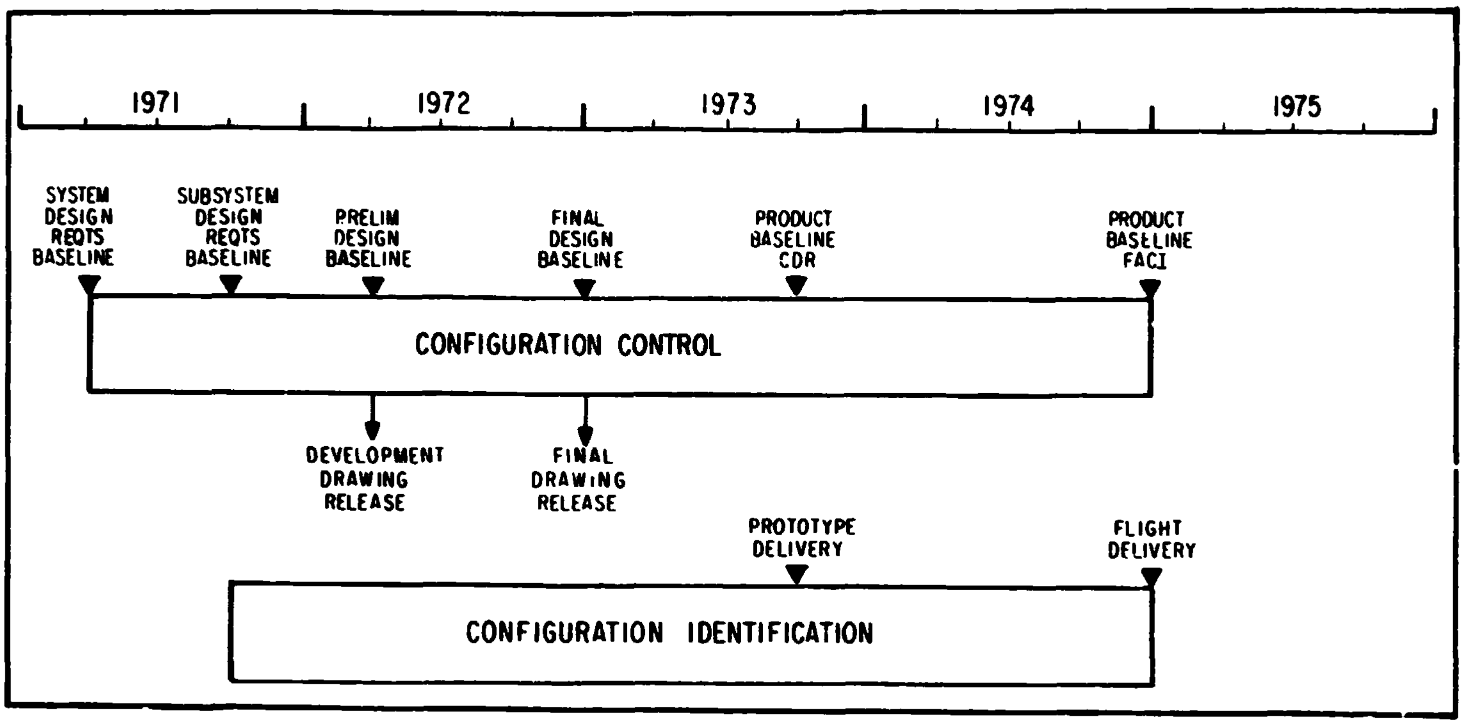

Fig. 3-8 Configuration Management Plan

3.7.1 Configuration Control

Throughout a complex program such as this, the state of the engineering is constantly changing. Chaos would occur in the fabrication, assembly, test and inspection activities unless the desired engineering has been identified. Therefore, a system of change control will be used on this program, and will evolve with the changing baselines as indicated:

- System design requirements baseline - change control based on EIS.
- Subsystem design requirements baseline - change control based on EIS and subsystem specifications.
- Preliminary design baseline - change control based on development release drawings.
- Final design baseline - change control based on final release drawings.

- Product baseline - CDR - Change control based on drawing status at CDR.

- Product baseline - FACI - Change control based on drawing status at delivery of the Flight Unit.

The Change Control Board (CCB) is an assembly of program personnel which considers the various changes that originate with the customer or within the contractor's team. Consideration of a change deals with any significant change in reliability; change in program schedule or program cost; and whether it is a record change. The CCB also determines the impact of each change and the board chairman processes the change according to the rules:

- Class 1 - Requires contract officer approval
  - Affects the baseline, interface, form, fit or function
  - Affects program schedule or cost

- Class 2 - CCB chairman approval only
  - Not a Class 1 change (e.g., record change)

Configuration control will only be applied to the Proto-Flight and Flight Unit end-items. The DVU is an engineering model and strict configuration accounting is not required. The Proto-Flight Unit will be a controlled build, as an end-item; but the level of change control applied will be that for an engineering model, since it is used for qualification.

3.7.2 Configuration Identification

The engineering baseline, to which all program efforts are referenced, must be maintained in an up-to-date status. Such configuration identification is established from the basic drawing tree, and is updated for each engineering change that is authorized. This identification list is maintained by the CCB chairman, and is authorized by him for use in procurement, fabrication, and inspection of hardware. The identification list is also used to identify the "as-built" configuration, as the inspection data are compared with the final list. This "as-built" record is the basis for identifying the delivered end-item, and is the baseline for any post-delivery changes.

3.8 ADMINISTRATION PLAN

The administration of the Photoheliograph program is defined in this plan. It includes the major tasks of: (1) maintaining an up-to-date contractual agreement between the parties; (2) maintaining and reporting the program schedule; and (3) maintaining and reporting the program costs. Each of these tasks is defined by the overall Phase C&D Plan shown in Fig. 3-1 and the program work breakdown structure (Fig. 3-2).

3.8.1 Contract Control

All aspects of the program will be covered by the baseline contract agreements, which reflect the program WBS and the scheduled milestone events. These baseline agreements will be updated by appropriate contract changes in accordance with any changes in the program requirements. Any contract changes will be incorporated in the WBS and the program schedule.

3.8.2 Schedule Control

One of the most critical elements of overall program control is the schedule established by the contractual milestones, as augmented by more detailed program milestones. These establish major checkpoints during the program, and will be used as the framework for time management. During the Photoheliograph program, a variety of activities will be underway at any one point in time. These activities can easily be organized into various logic paths that converge on the milestone events. These logic sequences form the basis for the PERT management tool that will be used to track the progress performance and identify the problem areas that lag behind.

Schedule reporting will be used throughout the program to monitor the progress toward the milestone goals. This reporting will be in the form of PERT computer reports, critical path reports, and bar charts. These reports will be derived from the baseline program logic and the major milestone dates.

3.8.3 Cost Control

Comprehensive cost control is required throughout the program to maintain a cost-effective and efficient use of money allocated to the program. Since the WBS identifies each of the major cost elements within the program, cost control will be based on the WBS. Furthermore, since the most expensive variable in the program is time, an effective management tool for cost control will be obtained by relating cost to time performance using PERT logic derived from the WBS. Each element of the WBS will have a starting and completing milestone event, and latest allowable completion time. The cost of performing that task will be measured with respect to the original estimate as the program progresses and the time estimates vary.

By measuring cost performance as a function of milestone progress, the entire program history and projections to completion can be established. With this knowledge, appropriate management decisions can be implemented. Also, accurate estimates of future funding requirements will be reported to the customer in a timely manner.

3.9 SPECIAL FACILITY REQUIREMENTS

Based upon the design concept for the Photoheliograph developed during the study, and on the program plan for Phase C&D, facilities requirements do not appear to present a major problem in the Photoheliograph Phase C&D Program. Other than standard aerospace facilities which will be required, the following are worthy of note:

- A large vertical vacuum chamber will be required for testing. This chamber will include either a heliostat or solar simulator, to be installed so that required precision is achieved.
- High-precision optical test equipment to verify subsystem optics performance and Photoheliograph system performance.
- Class 10,000 clean rooms
- Environmental test facilities for the following tests:

- Sine and random vibration
- Thermal
- Thermal-vacuum
- Electromagnetic compatibility
- Acoustics (subsystems only)

- Spectral calibration facilities

- Special order film processing

3.10 PROGRAM MANAGEMENT

3.10.1 Program Office

The program office to be established for Phase C&D will have total responsibility for planning, organizing, staffing, directing and controlling of the program.

Phase C&D will be headed by a program manager who is responsible for management of all aspects of the program. The program manager will be assisted in various program management functions staffed by project engineers.

Work assignments will be made by program management to the various line organizations participating in the Phase C&D Program. The program manager and his staff will then manage the performance of these organizations in conjunction with cognizant line organization management, to effect total Phase C&D management.

The program office will be organized into two major areas: (1) Operations; and (2) Planning and Control. These two areas will implement the specific plans for the major Phase C&D activities defined previously in Pars. 3.3 through 3.8. Further discussion of the Operations and the Planning & Control areas of program management follows.

3.10.2 Operations

The Operations area of program management will implement the engineering, manufacturing, and test plans. This will include the Photoheliograph design and development, fabrication and end-item test activities throughout Phase C&D. These functions are further defined in the following paragraphs.

Engineering Management

The engineering management function in the Operations area will be responsible for all engineering activities and design and development of the Photoheliograph instrument. This will include management of the system design, the detail design, design verification activities utilizing the DVU, and qualification of the Proto-Flight Unit. Additionally, this area will be responsible for design liaison with the customer and subcontractors. Upon completion of the design, this area will provide management of sustaining engineering throughout the fabrication and test phases of the Photoheliograph end-items.

Production Management

The production management function in the Operations area will be responsible for the fabrication of the Photoheliograph DVU, Proto-Flight and Flight Unit end-items. This area will provide liaison with engineering personnel during the design phases, and will provide management of sustaining production support during the system integration and test phases. Production management will also provide subcontract liaison as required.

End-Item Test Management

The end-item test management function in the Operations area will be responsible for Photoheliograph system integration, alignment, calibration and testing activities. This area will perform customer liaison relating to these activities , as well as similar liaison for subcontracts. Test management is also responsible for test plans, specifications, and procedures.

3.10.3 Planning & Control

The Planning & Control area of program management will implement the reliability and quality assurance, configuration management and administration plans. This will include program planning and program control throughout Phase C&D. The Planning & Control functions are further defined in the paragraphs below.

Reliability and Quality Assurance Management

The reliability and quality assurance management function in the Planning & Control area is planned to be responsible for the planning and implementation of all reliability and quality assurance requirements. This area will provide customer liaison for these activities, and will perform similar liaison on subcontracts. Reliability and quality assurance management will be responsible for the generation and maintenance of the customer-approved plans governing reliability and quality assurance.

Configuration Management

The configuration management function in Planning & Control is responsible for maintaining identification, control and accountability of all program documentation. This area will also be responsible for the configuration management plan, the Change Authorization Board, and the proper disposition of the resultant documentation changes. Customer and subcontract liaison on configuration management will also be provided.

Administration

The administration function in the Planning & Control area is responsible for the proper implementation of Phase C&D contract requirements into the program. This includes work authorization to the line organizations and subsequent performance monitoring. All PERT schedule and PERT cost effort will be performed by this area, to provide effective schedule and cost control throughout Phase C&D. Customer and subcontract liaison relating to the above activities will also be provided.

Section 4
PROGRAM SCHEDULE

The schedule for the program plan summarized in Section 3, has been developed from the logic diagrams based on the WBS. The logic diagrams for the entire program have been combined into a set of networks. Each network is characterized by a start and complete milestone. The networks are combined into a complete PERT operation that has been used to iterate the program schedule and to analyze the critical paths.

4.1 MASTER SCHEDULE AND MILESTONES

The major milestones for the Photoheliograph Phase C&D Program are identified in Fig. 3-1. The overall time-frame, for planning purposes, runs from the beginning of the second quarter of 1971 through the end of the fourth quarter of 1974, a total of forty-five months through Flight Unit end-item delivery. This total time-frame is commensurate with that experienced on Skylab-A experiments. The major activities planned during Phase C&D are as shown previously in Fig. 3-1. These correlate to Level 2 of the work breakdown structure. A brief discussion of each of these major activities follows.

The overall system design phase for the Photoheliograph will be accomplished at the outset of Phase C&D. This phase will result in the various system and subsystem specifications defining the design parameters.

The detail design phase is planned to begin after approximately three months and run to completion of the critical design review milestone. This phase will result in the release of engineering drawings required for fabrication of the Photoheliograph. A major milestone during the detail design phase will be the developmenc release of the initial engineering drawings for use on the DVU.

The DVU phase is planned to run parallel with the detail design phase. This phase will conclude with the completion of system testing of the Photoheliograph DVU.

The Proto-Flight Unit phase is nominally planned for eighteen months. This phase will overlap the DVU phase through completion of the DVU balloon tests. The Proto-Flight phase will conclude upon completion of qualification testing, the critical design review and delivery of the Proto-Flight Unit.

The Flight Unit phase is also planned for a nominal eighteen months, concluding at the end of 1974. This phase overlaps the Proto-Flight phase by approximately three months in the long-lead procurement and early fabrication stages. The Flight Unit phase concludes with the completion of acceptance testing and delivery of the Flight Unit Photoheliograph.

Reliability and quality assurance, documentation, and program management run throughout the duration of the Photoheliograph Phase C&D Program, concluding with the delivery of the Flight Unit Photoheliograph at the end of 1974.

The overall Photoheliograph Phase C&D Program, as planned, is commensurate with a launch during the second quarter 1976.

4.2 PERT NETWORKS

The PERT networks generated from the logic paths were integrated into the total program PERT operation. The networks that make up this total PERT are indicated in Table 4-1. These networks combine all Level 3 activities in the WBS. A summary network, Fig. 4-1, has been developed from these, which is analogous to the WBS Level 2 and the program plan in Fig. 3-1.

Table 4-1
PHOTOHELIOGRAPH PHASE C&D PROGRAM PERT NETWORKS

PERT Subnets	PERT Charts
System Design (1X-XX)	Telescope Module Instrumentation Module Support Module
Detail Design (2X-XX)	Telescope Module Instrumentation Module Support Module
DVU (3X-XX)	Telescope Module Instrumentation Module Support Module
Prototype (4X-XX)	Telescope Module Instrumentation Module Support Module
Flight (5X-XX)	Telescope Module Instrumentation Module Support Module
Reliability and Quality Assurance, Documentation and Program Management (6X-XX, 7X-XX, 8X-XX)	Reliability and Quality Assurance, Documentation and Program Management

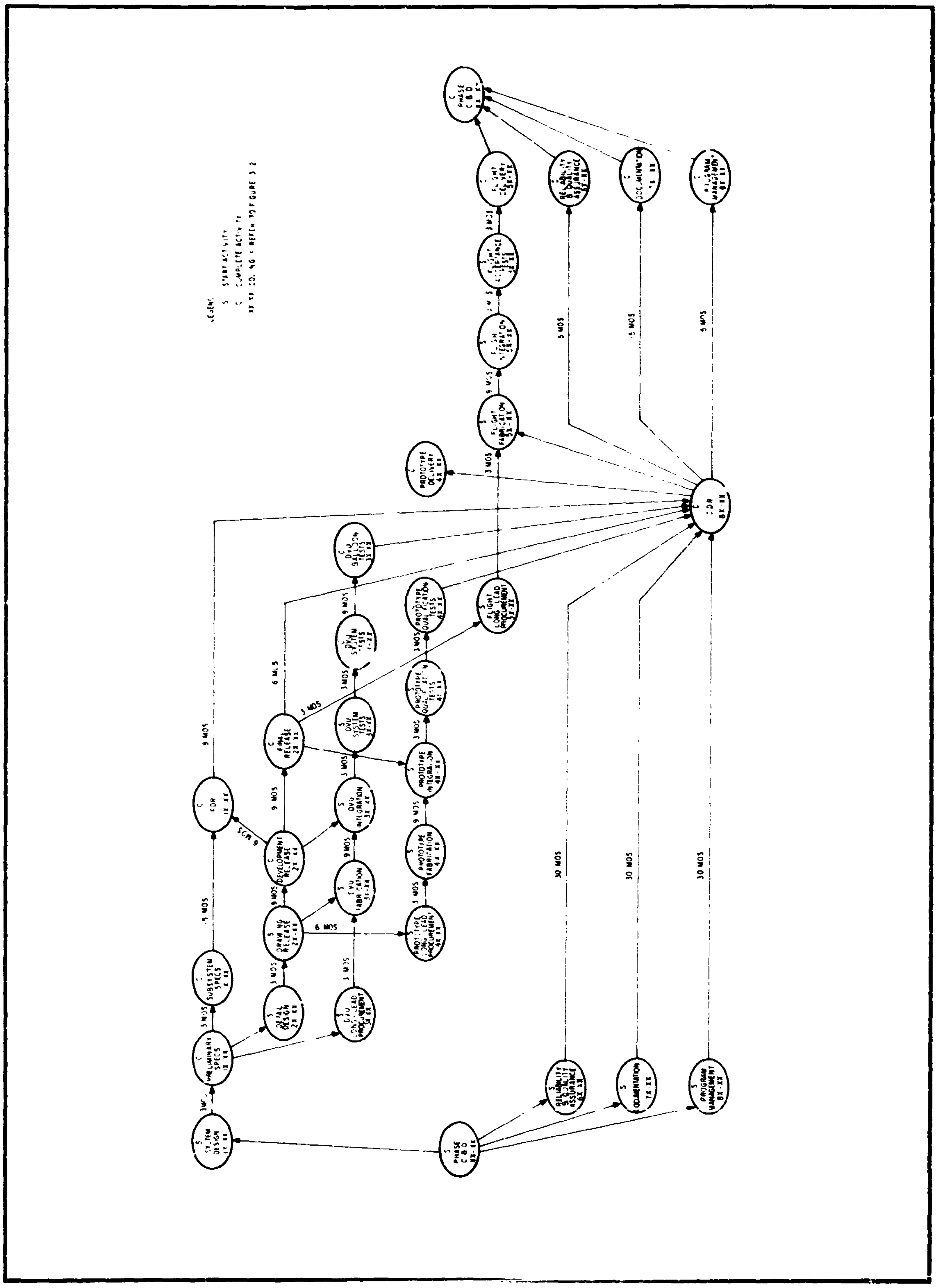

Fig. 4-1 Summary PERT Network (WBS Level 2) for Phase C&D Photoheliograph Program

4.3 SCHEDULE ANALYSIS

Analysis of the program schedule was performed by examining each of the logic paths in each network. The time estimates for each work task and the sequence of the work were reviewed to ensure that the final milestone (Flight Unit end-item delivery) could be met, and to ensure that each interim milestone along the way could be met. Logic paths that required more time than was available between milestones were adjusted or re-estimated to achieve an overall program schedule. Other logic paths that started prematurely for a given milestone were delayed in order to smooth out the manpower loading.

The complete set of logic paths was iterated until all paths were "positive" with respect to the major program milestones; that is, there was contingency time to perform the activities in each path. The am unt of contingency time in a program activity is a measure of the probability of meeting the milestone date that completes that activity. Our analysis of this program is summarized in Fig. ,-2, where the contingency time is shown for the three Photoheliograph modules for each end-item. The chart designation "good shape" indicates that all logic paths have 10 percent or more contingency time; "critical" indicates virtually no contingency time.

The Instrumentation Module for the DVU has a "critical" rating, due to the time necessary to develop the universal filter. Similarly, the Telescope Module for the DVU is marginal, due to the time necessary to develop the image motion compensation system. These critical logic paths are within the required overall program schedule, but development in advance would provide a wider time margin. All other logic paths h. /e healthy amounts of contingency time, as can be seen in 4-3, where the planning status of the several hundred major r h; is shown versus weeks of contingency time. With this b. a of schedule analysis we can confidently predict that the h Phase C&D Program can be carried out as planned.

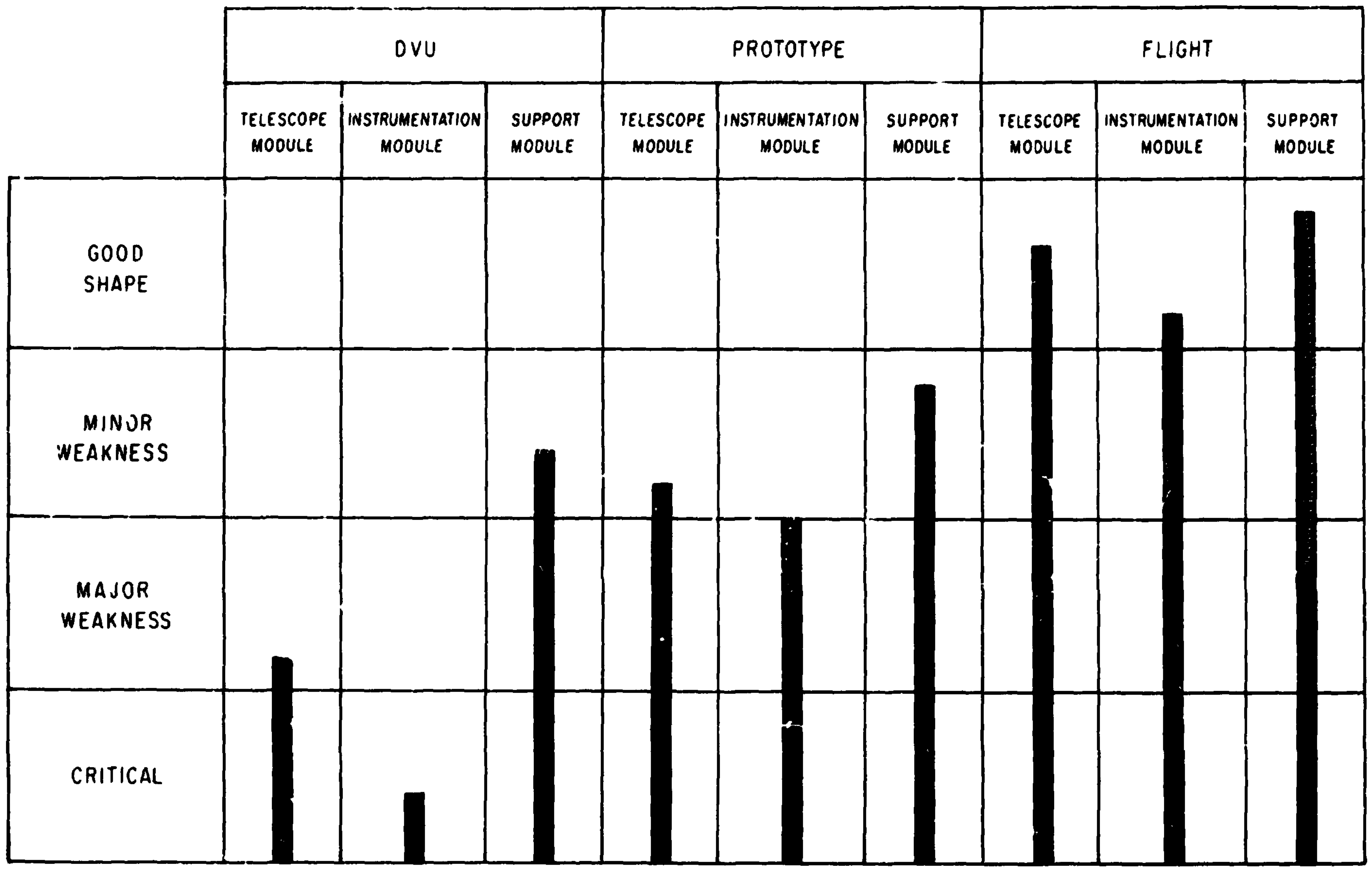

Fig. 4-2 Phase C&D Program - Summary Schedule Status

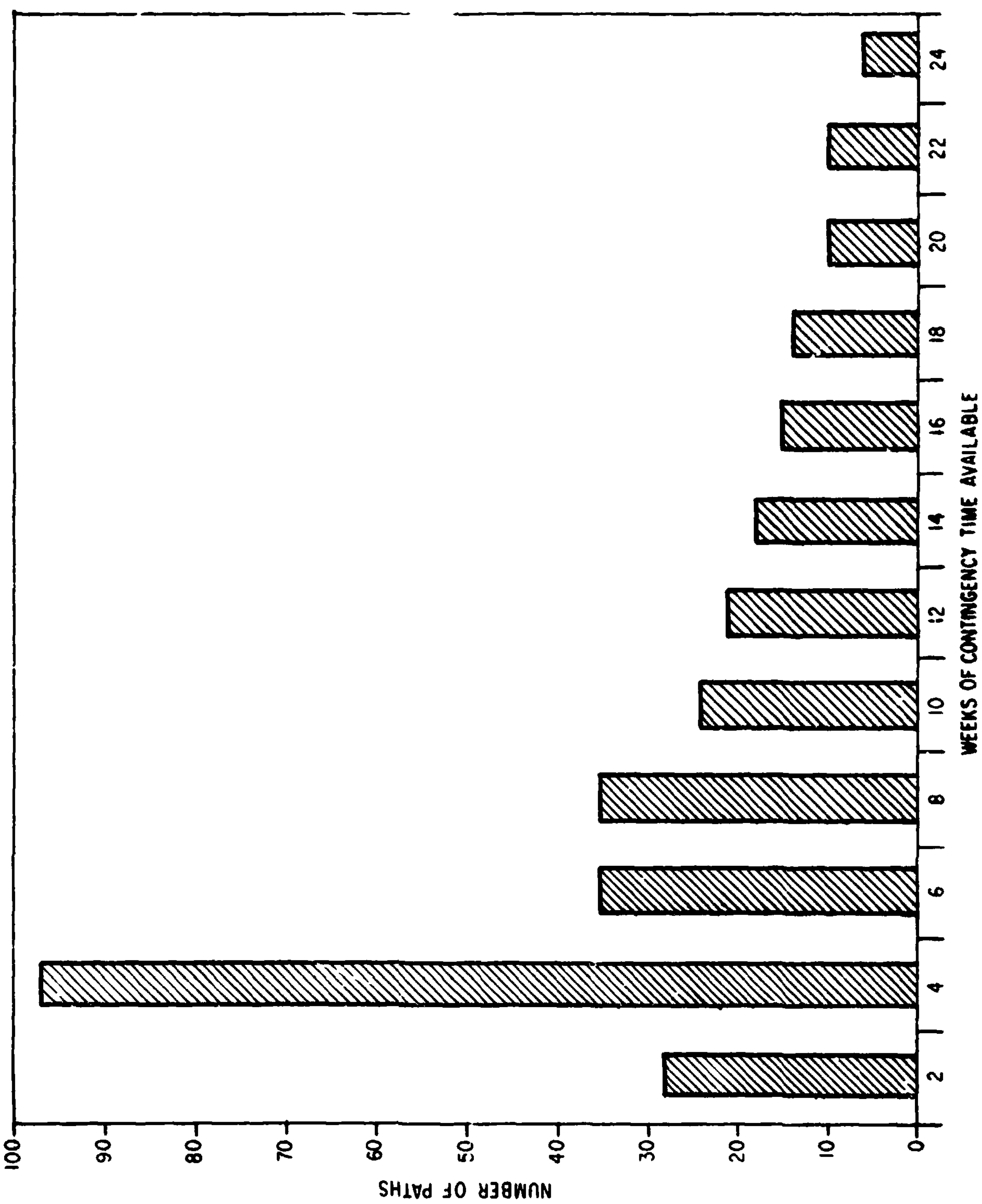

Fig. 4-3 Program Logic Paths Versus Contingency Time Available